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ECONOMICS.—*The function of research in the regulation of natural monopolies.*[1] E. B. ROSA, Bureau of Standards.

The social and political unrest of the present day, which manifested itself strikingly in the recent presidential campaign, is of course due to more than one cause. Senator Root in a notable speech recently delivered before the New York Chamber of Commerce, attributed this unrest in large measure to the mutual distrust and mutual misunderstanding existing between the leaders of the financial and industrial world on the one hand and the great body of the American people on the other. To a large audience of bankers, merchants, and captains of industry he said:

> There are hundreds of thousands of people outside our great industrial communities who think you are a den of thieves. There are hundreds of thousands of people who think the bankers and manufacturers are no better than a set of confidence men.
>
> We have before us now great and serious questions regarding the financial problems of the country, and this is what stands in the way of their solution: It is that the men who understand the finances of the country and the merchants engaged in great operations are under suspicion; great bodies of people will not accept what they say about finance. They will not accept what the experts say because they do not believe their motives are honest. . . . . On the other hand, what is your attitude toward the people? There are many in this room tonight who down deep in their hearts believe that great bodies of the American people really want to destroy their business and confiscate their property. Now, neither of these things is true; but one misunderstanding leads to conduct which seems to justify another.

[1] Address of the retiring president of the Philosophical Society of Washington, delivered February 15, 1913.

Senator Root then went on to say that there is nothing more important today than that by education and the spread of ideas such misunderstanding shall be done away with; that Americans shall interpret the spirit of popular government so that each shall be ready to do justice to the other, and every American shall desire the prosperity and happiness of every other American.

But while there is great force in what Senator Root says, it remains true that this social unrest springs in a measure from causes which the government can remedy.[2] The part which the government must play in our complex civilization is constantly increasing, and is immensely more important than in the simpler civilization of a century ago. In the early days the individual was much more independent, and each community was much less dependent on other communities than now. Society was simple, communication and commerce were limited, and relatively few laws sufficed. The twentieth century differs from the eighteenth in many respects, but in none more strikingly than with regard to the increasing complexity of business dealings.

The regulation and control of large corporations which have virtually secured the monopoly of particular industries is now receiving the attention of many of our leading scholars and statesmen, and the solution of the problem will be a triumph for popular government. The means that may be employed for this purpose are not so restricted as they formerly were. The public is becoming educated rapidly, and the constitution has greater capacities now than formerly.

State regulation of natural monopolies. While the federal government in the last few years has been striving to break up giant aggregations of corporations into their constituent parts, with the hope of getting these parts to compete with one another and so put an end to an undesirable monopoly, some of the states have been dealing in constructive fashion with another class of monopolies, and showing how they can be regulated and controlled to the end of conserving the best interests both of the public and of the stockholders. I refer to that very large and important

[2] In other words, the people acting co-operatively thru their chosen representatives can remedy.

class of corporations known as public utility companies, chief among which are the steam railways of the country, city and interurban electric railways, gas and water companies, electric light and power companies, and the telephone and telegraph companies. The federal government through the Interstate Commerce Commission has of course taken a leading part in this development, particularly with respect to the railways of the country, but the work done by some of the state public service commissions, prominent among which are the commissions of Massachusetts, Wisconsin, and New York, is of far-reaching influence and importance.

The attitude of the public regarding public utilities has been undergoing a profound change in recent years. Formerly a franchise for a street railway or gas company, for example, was usually granted without compensation to the city, with few, if any obligations on the company, with no control by the city over prices or service, and with extensions of the service into new territory optional with the Company. Competition was sometimes sought by granting a franchise to more than one company, but generally such competition, if any, made the service poorer to the public as well as the profits less to the stock holders. If the business was profitable and the franchises valuable, city councils would be corrupted, if necessary, to get what was wanted. And if the dividends were large, as they often were when no standards were set as to the quality of service and no limit set as to price, the capital would be sufficiently watered to keep down the dividends (capitalizing the value of the franchise, it was called). Occasionally a city became so dissatisfied with its gas or water or electric light company (either as to prices or service, or both) that in despair it built a new works, and two plants were operated where one, if rightly managed, would have served the public better.

Advantages of a monopoly. The change from this condition to the present (at least in certain states) is nothing short of revolutionary. It is now coming to be recognized that competition cannot regulate rates in public utilities, and that one company can generally give better and cheaper service than two. It is a waste of capital and a disadvantage to a city to have two sets of

gas or water pipes in the ground, or two sets of telephone or eletric light wires and poles encumbering the streets. Having two telephone companies in a city forces a large proportion of their patrons to pay for both services; two street railway systems generally give less satisfactory service and fewer transfers than one would do. In short, these utilities are natural monopolies, and the highest efficiency and lowest rates are only possible when each one has the entire business of a given city or territory. So long as the right to regulate public service companies was denied, the idea of granting monopoly privileges was repugnant, and hence competition was encouraged with the hope of escaping the ill effects of unregulated monopoly. But now that the right and duty of regulating all public service corporations is admitted by the companies themselves as well as by the courts, the ill effects of monopoly may be escaped and at the same time the beneficial results of economy and efficiency may be realized. To understand what effective regulation involves, we must consider the obligations imposed upon public utility companies, and the character of the service rendered by each.

When a community grants an exclusive franchise for a term of years or for an indefinite period to a corporation, with the right to regulate the quality of the service it shall render and the prices it may charge for such service, it undertakes a serious responsibility. The interests of the public must be safeguarded, but at the same time the interests of the company and its stockholder must be respected. A public service commission, equipped with a full knowledge of the technical, commercial and legal aspects of the business, and endowed with a judicial spirit, will see that the following duties are fulfilled by each public utility company in its jurisdiction.

1. To perform any duties especially prescribed by law.
2. To serve all who request service and make no discriminations.
3. To provide safe and adequate service.
4. To charge just and reasonable rates.

5. To fulfill its duties to its stockholders honestly and efficiently.[3]

Regulation of a gas company. For example, a gas company receives a franchise to manufacture and sell gas for light, heat and power in a given city, for a term of years, the city perhaps to have the right of purchasing the plant at the end of the franchise period. The quality of gas and the character of the service furnished, and the prices charged, are to be fixed by the public service commission.

The commission must see that the company runs its mains into all the streets of the city; so as to give service to all, that uniform rates are charged and no rebates are allowed to favored customers; that service charges if made are reasonable; that the gas is of good quality, and as free from impurities as possible; that its heating value and candle power are kept up to the standard specified; that the methods of testing and the instruments employed are up to date and satisfactory, and the persons doing the testing are competent; that the pressure of the gas is sufficient and not too great and does not vary enough to be dangerous; that gas appliances used are as safe as can be obtained, and connected in an approved manner; that the mains are properly located and properly protected from extremes of heat and cold; that the meters are kept in good order and tested from time to time as to their accuracy; that the prices charged are as low as possible, consistent with a reasonable dividend to the stockholders; that the books are kept in an approved form, so that the state of the business can readily be determined by the commission; that proper allowances are made for plant depreciation, or proper sums expended for upkeep; that no new stock is sold without approval by the commission, and that all dividends shall be from actual earnings, but that if actual net earnings are more than necessary to pay a reasonable dividend, the price of gas shall be

[3] This of course supposes that the commission has been given the necessary authority by the state legislature. Many of the public service commissions were created as railroad commissions; and of these, some have had their functions extended to cover only a part of the duties mentioned above.

reduced. This usually involves an appraisal of the company's property to determine whether the capitalization is fair. From time to time the specifications for the quality of the gas and the methods of testing must be revised; the question may arise as to what candlepower or heating value will give the best service under prevailing conditions; new methods of manufacture, new appliances and new uses for the gas will all bring up new questions; and the commission must be prepared to consider and decide upon all kinds of scientific, engineering and commercial problems as they arise in connection with the regulation of gas companies.

These duties are so many and so varied that one might suppose that it would be impossible for a commission to accomplish them all even for a single company, much less for all the gas companies in a state. If it had never been done, it would indeed appear doubtful. But these functions are being performed (at least in large part) so successfully in a few states that many of the other states are looking forward to doing it as soon as their commissions are prepared for the work. The gain from such regulation is not alone to the public, which pays for and uses the gas. The company is saved from unfair and hostile local legislation, which often forces resort to the courts, always an expensive and often unsatisfactory experience. The business is more stable, customers are better served and better satisfied, the credit of the company is often improved, new stock sells more readily and at higher prices, as the public knows the condition of the business and there is less risk to the investor. Stock manipulation is prevented, and those who profit by that process are the only ones to suffer.

Regulation of an electric light company. Similar duties devolve upon a public service commission with regard to other utilities. Electric light companies are regulated with respect to their schedule of rates; discriminations which are so frequent under ordinary circumstances must be prevented; wires, whether overhead or underground, must be run in such manner as to reduce the danger to the public; high potential wires must be especially guarded to keep them from telephone and other low potential wires; alternating current transformers must be grounded on the secondary side, and the grounds must be made according to

approved specifications; the steadiness of electric potential and uniformity thruout a given city must be satisfactory; proper precautions must be taken to safeguard the lives of the linemen and other employees of the company; the meters must be frequently tested and provision made for extra tests on complaint; portable and station instruments must be tested; lamp renewals must be regulated and prices approved for other than free renewals, and rules and regulations made (in the absence of local rules) with respect to streets lights.

Regulation of other utilities. Street railways and interurban electric railways must be regulated with respect to kind and quality of cars; the speed of cars and car schedules; kind of brakes, headlights, doors, and other safety appliances; the method of car heating and amount of heating required; the method of car lighting and the quality and amount of light that must be supplied; how the current is distributed from the sub-stations to the cars and the variations in voltage permitted between sub-station and cars; how the railway current is returned from the cars to the sub-stations, in order that the resulting electrolysis may do the minimum of injury to gas and water pipes, lead sheathed cables and other underground structures; the repairs and upkeep of roadway and rolling stock; the fares to be charged and the conditions under which free transfers are issued; the wages paid employees and hours of labor; the conditions under which new stock may be issued; approval of plans for extensions or alterations of system; etc.

Telephone companies must be regulated with respect to method of running their wires, so as to give the best and most reliable service possible under given circumstances; when and where wires must be put underground; the precautions to guard overhead wires against coming into contact with high potential electric light or power wires; when and under what circumstances telephone and high potential electric wires may be put on the same poles; the rates to be charged for different classes of service, both local and long distance; the service arrangements between different companies, the restrictions imposed by telephone companies respecting private exchanges and extensions; discrimina-

tions by a powerful company against smaller independent companies, etc.

Both the Interstate Commerce Commission and the state commissions deal with problems arising in connection with the regulation of the railroads, and these problems are numerous and of great importance. The first class of problems is connected with the fixing of freight and passenger tariffs, and discriminations in rates as between one locality and another or between one shipper and another. The second class of problems has to do with the operation of the road, with the safety and the adequacy of the service. This includes the question of the character of the roadbed and rails, the kind and quality of the engines and cars, the brakes and signalling apparatus, the kind of headlights and the candlepower and distribution of the light from the same; the heating, lighting, and ventilation of cars; the investigation of accidents, the weighing of freight and the testing of the scales, including the scales on which empty and loaded cars are weighed. These and many other questions may come before both state and federal commissions, but not all of them have been fully considered as yet by either. Similar duties pertain also to other utilities that are essentially monopolies, as telegraph companies, express companies, sleeping car companies, water supply companies, local express, transfer, and cab companies. Insofar as these utilities carry on an interstate business, they are also dealt with by the federal interstate commerce commission.

Co-operation necessary in regulation. It appears from the above formidable, altho incomplete, list of duties devolving upon a state public utility commission that to fully measure up to its responsibilities would require a considerable staff of engineers, accountants, and scientific assistants, besides its traveling inspectors and administrative officers. To decide many of the questions arising requires more technical knowledge than the experts either of the commission or the utility companies possess. Indeed, many of the questions can only be answered by extended researches carried out by scientists, engineers or statisticians, working with the best of facilities. The interests at stake are in the aggregate so great that such researches ought to be made, and yet

the cost would be too great for every state to do the work independently, or even for the richest of the states to undertake it alone.[4] The best way in which the work can be well done and kept up to date is for all the states to co-operate, and for the federal government to assist and coordinate the work. This is being done to some extent already, altho comparatively few of the states as yet have commissions that are handling public utilities generally, and hence the work is only fairly begun. On the part of the federal government, the Interstate Commerce Commission and the Bureau of Standards are co-operating with the state commissions, the latter with regard to standards and engineering questions which fall within its province. Some of these questions may be mentioned briefly.

Instruments and standards. The instruments and standards employed in the measurement of heat, light, and electrical power, have been the subject of much study and investigation at the Bureau of Standards. The thermometers and pyrometers of various kinds employed in temperature measurements, and calorimeters of different types for use in measuring the heat of combustion of gases and solids, are calibrated and certified by the Bureau and standard samples of certified calorific value are furnished, so that the testing apparatus of public service commissions, public utility companies, and consulting engineers will agree (or special tests be made if they disagree) and causes for dispute are thereby removed. The methods of testing with such apparatus have been studied by the Bureau, and sources of error in apparatus and methods determined. As manufacturing methods are developed and refinements in works control are introduced, greater accuracy

[4] Extract from Prof. R. T. Ely, in his Outlines of Economics, 1908: "The tasks which confront such commissions are stupendous, and the expense of conducting their work, when it is properly conducted, is enormous. . . . . On the whole however, it is fortunate that the public have resolved to give this method of reform a thoro trial. It seems to be the next logical step in the evolution of natural monopoly, and does not appear to be attended with any grave danger. If it fails it will at least have trained up a corps of public servants thoroly familiar with the operation of public utility enterprises, and will at the same time have thoroly convinced the people that there is no other alternative but public ownership and operation." This was written five years ago, and much progress has been made since then.

in testing is required, and it is a great advantage to the industries to have uniform and reliable instruments, standards and methods.

The same may be said respecting the measurement of light and illumination. The candlepower of a gas flame depends upon the quality of the gas, the kind of burner used, the height of the barometer, the amount of moisture in the atmosphere, and the degree of purity of the air in which it burns; hence, if the quality of the gas is to be determined (in part) by the candlepower given, it is necessary that the test be made under very definite conditions. The Bureau has done considerable work on flame standards employed in gas testing, but much remains to be done in this respect. Photometric standards are supplied by the Bureau for use in testing electric lamps of various kinds and colors, and gas standards are calibrated and certified. Thus, uniformity of value in light measurement is secured for the whole country, and indeed by means of international comparisons made by the Bureau for the whole world, the international candle being the name of the unit of light universally employed in this country. Calibrations are also made of photometers and auxiliary apparatus. Similar uniformity, together with a much higher degree of precision, have been attained in electrical measurements. Electrical energy is sold by the kilowatt hour or the kilowatt year (or a combination of the two) and a large amount of testing is done by the companies and commissions to insure accurate measurement of the energy delivered. Here again uniformity and accuracy are promoted by having a national laboratory for calibrating and certifying standards and instruments, and settling such disputes as may arise from disagreeing measurements. A large amount of work has been done by the Bureau to secure and maintain accurate standards and instruments, but much remains to be done, particularly with reference to the specifications of instruments and apparatus and the improvement of methods of measurement and testing.

In addition to its work on instruments and standards, the Bureau has carried out other investigations which have a bearing on the work of the public service commissions. One of these is concerned with the specifications of illuminating gas, and the methods of testing to be employed in controlling its quality.

Technical specifications for gas companies. Among public service utilities, none has been for so long a time and in so great detail subject to legal requirements and restrictions as the gas business. Such regulation is of course intended to insure good service. Many elements go to determine good or poor service, the principal of which (chemical purity, heating value, candle-power, and condition as to pressure of the gas) are enumerated and defined more or less completely in many of the gas ordinances now in force, together with the tests that shall be made and the penalties for failure to meet the requirements. These ordinances are sometimes, therefore, very technical and contain detailed specifications. In other cases the specifications are very meager. In some cases old ordinances long since out of date, so far as their technical specifications are concerned, are still in use; in other cases, old ordinances have been extensively amended; in still other cases entirely new ordinances have superseded old ones; in many cases no regulatory ordinances have ever been adopted. In some states possessing state commissions, the requirements have been fixed by the commissions. But in most states (and in all until recently) regulatory ordinances have been prepared and passed by state legislatures or city councils. The process of adopting such an ordinance is often long and painful. Suspicion, antagonism, and often political considerations combine to make the negotiations difficult, and sometimes it amounts to a long drawn battle. The representatives of the city endeavor to get all they can for the public, the company yields as little as possible. The result is generally unsatisfactory to both. Because the standard of performance demanded of gas companies in different cities and states was so different, and because so much difference of opinion existed among experts as to what could fairly be required of a gas company under given conditions, the Bureau of Standards took up about three years ago a careful study of the subject of state and municipal regulations of the quality, purity, and pressure of illuminating gas supplied by gas companies.

Investigation concerning regulation of gas companies. A compilation of all the state laws and city ordinances in force in the country was first made, and their technical requirements tabu-

lated. A detailed study was then undertaken of the various features of such laws, and an attempt made to formulate a model law that should contain reasonable standards of quality, purity, and pressure, and a reasonable set of operating requirements. In this study, a large number of the best informed gas experts in the country were consulted, and many gas plants visited. In this work the Bureau has been assisted by the responsible officers and members of the technical staffs of gas companies, and by members of public service commissions, gas inspectors, and consulting engineers. The Bureau has endeavored to consider all sides of the various questions involved, and has of course received very conflicting opinions on some questions. It has been a source of great gratification to those conducting this investigation to see the fairness and broad minded spirit shown generally by representatives of the gas companies in discussing questions that affected them so vitally. They have met a spirit of fair play by a corresponding willingness to reach just conclusions.

The results of this investigation were published by the Bureau of Standards, and the paper has had a wide circulation and careful study by those most interested in the subjects treated. Since its publication, the Bureau has continued to study the subject, and is now preparing a revision of the first edition. The compilation of laws and ordinances will be revised and some important changes will be made in the model ordinance proposed. These changes are, however, being discussed very fully before publication, both with representatives of the public service commissions and of the gas companies, the latter including a special committee of the American Gas Institute.

The position of the Bureau in this matter, as in so many others, is advisory. It has no authority to enforce its conclusions and no disposition to suggest federal legislation or regulation. It acts as an unbiased co-ordinating agency, to formulate the results of its own and other's investigations and to give expression to the concensus of opinion of those best qualified to express opinions on technical questions of great practical importance.

A second investigation (already alluded to) is in progress on the methods and instruments employed in testing gas for its

heating value, its candlepower, and its chemical purity, as well as in testing meters and measuring gas pressures. This will be embodied in a separate publication which will be frequently revised and kept up to date, in order to be as useful as possible to gas inspectors and engineers in determining whether gas meets the specifications under which it is sold.

A third investigation scarcely begun, but which is much needed and deserves extensive study, is on the safety and efficiency of gas appliances. Too many fatal accidents result from defective gas appliances, and the contamination of the atmosphere thru imperfect combustion due to defective appliances is a serious matter, even when no fatalities result. This is a question in which co-operation of all the interests concerned cannot fail to yield important results.

Investigations of electrolysis. Another important investigation carried out by the Bureau of Standards which also concerns public utility companies is the damage by electrolysis produced by street railway currents flowing thru the earth, upon gas and water pipes, lead covered cables belonging to telephone, telegraph, and electric light companies, and the reinforced concrete foundations of buildings and bridges. Such insulated double conductor systems as those of New York, Washington, and Cincinnati provide for the return of the current to the power houses without flowing thru the earth, but most cities use the single overhead trolley, and permit the current to return in part thru gas and water pipes and other underground conductors. Where the current leaves such metal conductors, the latter are corroded electrolytically, and in some cases holes eaten thru, thereby interfering with the service and involving expensive repairs. Many remedies have been proposed, but as yet comparatively little has been done to cure the evil. The Bureau undertook a thoro study of the question for the purpose of testing some of the proposed remedies and arriving at a solution of the difficulty, if possible, that could be applied generally. This investigation is not yet completed, but already valuable results have been reached and it is hoped that shortly information will be made available for the use of the street railways that will permit them

greatly to reduce the volume of the currents flowing thru the earth without unreasonable expense, and that will enable the public service commissions to deal more intelligently with the question. The problem is becoming each year more acute since the volume of electric current used is each year increasing as the traffic increases, and the damage produced is therefore increasing at an increasing rate. Many law suits have arisen because of this damage, and such litigation is expensive because of the large amount of conflicting expert testimony adduced and the long time consumed in the trials. Money expended intelligently in solving the problem generally yields better returns than money spent in litigation.

In England and some continental countries, there have been rules on this subject which have served as a guide to the electric railways in building their roadways, and hence, they have been saved very largely from the evil effects of electrolysis, altho at a somewhat increased first cost. In this country, the subject was neglected for years. In the absence of public service commissions or similar bodies to establish regulations, and no government agency to take the lead in the investigation, the matter has been entirely neglected in many cases until the serious damage resulting has made the question a very acute one.

Life hazard in electrical work. Another question affecting public utility companies is the life hazard in electrical work. There are altogether too many preventable fatalities due to high potential electrical circuits not only to employees of the electrical companies but also to the public. In many cases such accidents could have been avoided if the companies had taken greater precautions, either by instructing their employees more carefully, or providing them with rubber gloves and other protective devices, or having repairs made only on dead lines, or using more substantial and more expensive construction, or running the high potential transmission lines on private rights of way instead of on the highway, or keeping the dangerous wires away from telephone wires and on separate pole lines, or taking still other precautions which experience shows are necessary. The long distance transmission of power is being resorted to more and more, and higher

voltages are being used than a few years ago would have been thought possible. One thousand volts is a dangerous voltage, but transmission at fifty to a hundred thousand volts is becoming common. As water power is utilized more and more, the country will finally be covered with a net work of high potential transmission and distribution lines, and it is a matter of vital concern that all reasonable precautions be taken in the construction and operation of such lines. So long as public utilities were regarded as private business and a company was free to make as much money as possible and invest as little as possible in its plant, the tendency was to economize unduly with respect to protective devices, and any construction that was more expensive than the mechanical or electrical requirements demanded, was avoided. But when we regard railroads, electric light and power companies, and telephone and telegraph companies not only as public utilities, but as quasi-public institutions, and permit them to charge enough to make a good profit, but to make the rates as low as good service permits, then it is seen that the public pays for the cost of protection, and it is entitled to require that every reasonable precaution be taken to safeguard human life. This latter is the view which is now becoming general, and the public service commissions are therefore greatly interested in making rules and regulations worked out in such a way as to be capable of enforcement upon the electrical companies. On the other hand, the electrical companies themselves are anxious for such information. It is not necessary to make original investigations in every case; it is often a question of collecting and digesting the information already in existence, and with the co-operation of numerous agencies which stand ready to assist, work out a body of rules and regulations that will be as useful as possible. Congress has recently made a special appropriation to permit the Bureau to undertake such a study of the life hazard in electrical work, and it is hoped that valuable results may be accomplished.

Railroad scales. Another investigation of great practical importance, in which the Interstate Commerce Commission and the Bureau of Standards are co-operating, is the investigation of the accuracy of railroad scales, especially car scales, for weighing

freight. Freights to the amount of two thousand millions of dollars are annually collected by the railroads on weighings made with scales, most of which are seldom tested and, except in three western states, never officially inspected. Numerous disputes and complaints could be avoided if the scales were officially tested and certified, and if provision were made for retesting on complaint. Certainly, it is as important to test large scales as small ones, and the cost of doing so is trifling in comparison with the enormous interests at stake.

Locomotive headlights. Another subject with which some of the state commissions have dealt is the kind of headlights used on locomotives, their candlepower and reliability. In some states legislation has been enacted requiring a particular kind of headlight. It has been charged that such legislation in some cases has been inspired by commercial interests. In one state the commission issued a rule requiring a certain candlepower but not specifying how it was to be measured or exactly what was meant. The railroads, contending that the order was ambiguous, impossible to comply with by one interpretation and undesirable by another interpretation, appealed to the courts. After a lengthy and expensive litigation, the order of the commission was set aside. This case is cited to illustrate the need of full technical information by state commissions before issuing mandatory orders, and also the hardship to railroads or other public utility companies to be obliged to contest in the courts orders that work a hardship and which would not have been issued if full information had been at hand. There is great need of further investigation of the subject of headlights for use on steam and electric railways, to determine the best service that different types are capable of giving, and to formulate rules that could be enforced by the commissions. Some railroads economize unduly on the maintenance of headlights; in the interest of safety to the public, wise regulations should be in effect.

Car lighting. The lighting of cars (both steam and electric) is another practical matter that has not received the attention that it deserves. Most people read more or less on trains and street cars, and with many who ride a long distance to and from

business, this is their best time for reading. As a rule, however, the lighting of cars is insufficient and the arrangement of lights is often atrocious from the point of view both of the passengers who are not reading and those who are. Eye sight is too precious a possession and too easily injured to justify the continuance of poor lighting of cars. Better light is required than would be necessary if the cars were not moving. The problem is different on electric cars from what it is on steam cars, because in the former the current for lights comes from the same circuit that supplies the motors, and hence great variations occur due to the fluctuating voltage on the trolley wire. To secure better lighting (1) a steadier voltage should be available, (2) better lamps should be used than are generally seen in electric cars, (3) a greater quantity of light should be available, and (4) the lamps should be so shaded and so located as to keep the glare out of the eyes of the passenger, and yet give good illumination for reading. The immense importance of this subject can only be realized when one considers the millions of people who daily spend a considerable time in steam or electric cars, and how much better the service would be if the cars were pleasantly and sufficiently lighted. The public service commissions have it in their power to effect an immense improvement in this respect, but first a thoro investigation should be made, with the co-operation of the railroads, to show what are the best methods to follow, and what it is practicable to accomplish with present resources.

Heating and ventilation of cars. Another question of great practical importance is the heating and ventilation of cars, including Pullman sleeping cars. Any person who has sweltered in an overheated, unventilated lower berth of a sleeping car (and who has not), will allow that there is great room for improvement. Surely the resources of American invention have not been exhausted in this direction, nor, indeed, with respect to heating and ventilation of day coaches. It is one of the functions of public service commissions to see that the health and comfort of the public are kept in view by the utility companies, and if it can be made clear what should be done in this respect, the way to reform is open.

Railway accidents. Another line of work which deserves an immense amount of investigation and study, and co-operation between the states and the federal government, is the prevention of railway accidents. Much has been done and is now being done, both by federal and state agencies, and by the railway companies; but far greater sums of money might well be expended by the states and the federal government in a systematic investigation of all phases of this question. It is nothing short of a national disgrace that American railways should kill and injure so many more people than do the railways of European countries, even where the speeds are as high and the passenger traffic as heavy. Life is too cheap with us, and the penalty for disasters too slight. The causes of these accidents are partly physical and partly psychological; no doubt greater attention given to the subject of how to prevent both kinds of accidents would be abundantly rewarded.[5]

Other subjects deserving research could be named that fall within the province of the public service commission, but enough has been said to show how important are their functions apart from the duty of fixing rates and preventing discrimination. These illustrations show how much better it is for the public as well as the companies that the commissions regulate by co-operating with and assisting the companies instead merely of dictating to them what they shall do or shall not do; that the scientist, the engineer, and the statistician are more useful to them in their work than the lawyer; that the bar of public opinion is more effective than the courts in enforcing their decrees. Many of these utilities are operated by big corporations, owning scores of plants in many states; in the case of the telephone and telegraph,

[5] A recent writer states that 19,377 more persons were injured on railroads in the United States in 1912 than in 1911, and commenting on the slight amount of scientific information that has been collected regarding the causes of accidents, he adds:

"The railroads of this country carry so many passengers and so much freight that in one year they are able to charge three billion dollars for the service. And yet it is admitted that no accurate engineering data showing the actual stresses which are set up in railway structures by locomotives and cars of different weights and moving at different speeds has ever been gathered."

they are gigantic systems operating over the whole country. It is therefore important that the rules and regulations in the different states shall be as nearly uniform as possible. Hence, in order to reach wise and just conclusions, and to secure uniformity, it is important that the states co-operate with one another, and the federal government can serve as a valuable aid and co-ordinating force in this co-operation.

The results that are being attained in this way are only beginning to be realized. They will be of invaluable benefit, not only to the public served, but to the companies themselves, and to the cause of good government. With the utility companies under the control of business-like state commissions, the business is better managed,[6] discriminations in rates are eliminated,[7] the utilities are taken out of local politics, and the possibility of pure municipal government in America is enormously enhanced.[8]

[6] B. H. Meyer, speaking on the Wisconsin Public Utilities Commission, at the Pittsburgh Meeting (1908) of the National Municipal League, said:

"The utility law is working a revolution in business management. . . . . Many of the utility companies have not been operated on a business basis; in fact, it is probable that a good many of the managements did not have the remotest idea as to the exact standing, from a business point of view, of the plant, they were operating. Uniform accounting and rules governing the service and the regulation of ratio, compel the adoption of business and scientific methods. This is resulting in nothing short of a revolution in management."

[7] The whole state of Wisconsin was literally streaked and plastered with discrimination in the rates of utilities, and in all the rest of the country, where the extent of the discriminations have not yet been determined, as they have been in Wisconsin, it is quite probable that discriminations similar in character and extent likewise exist."

[8] Governor McGovern has this to say regarding the utilities and politics in Wisconsin:

"Times were in Wisconsin when the railroads ran or tried to run the government of the state, and the minor utilities sought to boss the cities, towns and even villages. They contributed liberally to campaign funds, urged their supporters and lobbyists to become candidates for public office, and in close election districts colonized voters in the old conventional way. Now, one and all, they are in this sense absolutely out of politics. There is, indeed, no reason now why public service corporations in Wisconsin should wish to dabble in public affairs. Their relations to the people of the state have been definitely and finally determined. They no longer have anything to gain or lose by intermeddling in politics, and apparently they have decided to retire for good. What the elimination of public service corporations from participation in political campaigns signified in the purification of public life, no one here needs to be reminded."

One of the best results of the method of regulation by public service commissions is the publicity it secures of the affairs of the company and the confidence it establishes in the public mind in the various utility companies. The suspicion and distrust which Senator Root emphasized so strongly in his New York address is everywhere felt toward these companies when their affairs are kept secret, and especially when the service is poor and the dividends good. Controversies arise which sometimes degenerate into bitter and partisan feuds. Who can feel kindly toward the management of a street railway company if he is usually compelled to ride as a strap hanger, or toward a gas company if the rates are excessive or he believes that his meter races, or toward any company that appears to regard its franchise as the deed to a private monopoly. If the service is improved or the rates reduced as the business grows more prosperous, the people as well as the stockholders derive benefits from success. The public soon realizes that utilities so conducted are in effect partnerships between the public and the stockholders, and are willing that the latter receive increased dividends with increased prosperity if the public is permitted to share the fruits of success. The sliding scale of prices for gas is a successful example of this system, but it is also realized in many cases where a sliding scale of prices has not been fixed in advance. The regulation of prices by a commission gives in effect a sliding scale, by which either the price goes down or the quality of the service goes up, as the success of the business justifies it. For want of a Public Service Commission in the District of Columbia, the Interstate Commerce Commission has recently been exercising the functions of such a commission with respect to the street railways, and with good effect. There is great need of a full fledged Public Service Commission in the District, and it is hoped that Congress in its wisdom will respond to public sentiment and establish such a commission.

How infinately better is this method of regulation than the building of publicly owned utilities to compete with private plants already in existence. For a state or city to say that it is impotent to regulate a public utility is a confession of weakness; but there is far greater difficulty in city control than in regulation by state commissions. Except, perhaps, in the largest cities, it seems

much better to have strong state commissions, well equipped with technical assistants, than to have separate commissions for each city. And with the co-operation of other states and the federal government, any state commission can establish its work with only a fraction of the effort and expense required by those states that have pioneered the movement.[9]

Turning now to the great industrial and financial corporations popularly called trusts, the question suggests itself whether it is possible for the government to regulate them in a manner similar to the regulation of the natural monopolies we have been discussing, so that full publicity may be secured, the rights of the public may be conserved, and at the same time the rank and file of the stockholders will be protected from the vultures that often hover over the executive offices of such concerns. One cannot say that it will be done as easily, but it is coming to be believed that the general method adopted in the regulation of public utilities is the right one, namely, less dependence on law and the courts, and more dependence on engineers, statisticians and business experts; that the government should prescribe affirmative duties for the giant corporations, and not merely negative ones; that a constructive policy that would benefit both the business concerns and the public they serve should be sought, rather than a retrograde policy that is no benefit to the business and does no good to the public. If such regulation could be realized, and consolidations and promotions in business could be limited to such as would benefit both the public and the stockholders, and not merely big financiers and promoters, it would be a notable achievement in our political as well as economic history. It would assist mightily in the peaceful settlement of industrial disputes and in the bringing of a better understanding between capital and labor.

It is just as reasonable to expect the government to perform this function of regulation of monopolies as to expect it to adjust international disputes by arbitration rather than by war. It is not socialistic, but rather the reverse, for it is the alternative of state ownership. In Germany the cities are great business

[9] Writing in 1908, Professor Ely said: "States having commissions empowered to enforce uniform accounting will constitute great economic laboratories in this connection during the next quarter of a century."

concerns operated by business men for the benefit of the people, and as such they are models for the whole world. They own and operate most of the public utilities themselves, and do it well, and hence the necessity of public regulation is there less felt altho it has been practiced for many years. But in this country, municipal ownership has been less successful, except in the case of municipal water supplies.

There have been three stages in the modern history of natural monopolies. In the first they went unregulated, being operated for the profit of the owners and exploited for the benefit of financiers. In the second stage, regulation was by legislation and law suit. In the third, regulation is by commission; the regulation is more complete, as well as more intelligent, and co-operation and publicity are the keynotes of the method.

The large industrial corporations which have virtual monopolies, are mainly in the first stage, altho some are in the second. Whether they will finally come to the third stage, and be regulated by the methods now applied so successfully to natural monopolies, remains for the future to determine.

If state regulation of natural monopolies becomes as general within a few years as it promises to be, and if it is as successful generally as it has been in the few states which took it up first, it will solve the problem of public utilities and largely solve the problem also of good municipal government.

The signal success of the Wisconsin Commission was largely due to the influence of the University of Wisconsin. In its personnel and methods it was a scientific commission, and entered into its work with the spirit of the investigator. Its spirit and its methods have been adopted by some of the other state commissions, of which a larger number have been created recently and are now taking up their work.

If the administrative officers of the commissions are assisted by scientists, engineers, and economists, and the work is done in a judicial spirit, as new problems being taken up as a scientific research would be, the states and federal government acting in full co-operation, with the experience of each available to all; if the work is done in that way we may be certain that success will be sure and permanent.

MINERALOGY. *The determination of the order of agreement between observation and theory in mineral analyses.*[1] FRED. E. WRIGHT, Geophysical Laboratory, and C. E. VAN ORSTRAND, Geological Survey.

In a recent number of this Journal,[2] Dr. W. T. Schaller published an interesting note on "The Calculation of Mineral Formulas" in which he showed that the ordinary method of calculation—by first reducing the weight percentages of an analysis to mol numbers[3] and then dividing these by one of the mol numbers thus obtained—furnishes results whose degree of approximation to whole numbers is less than that of the values derived by a new method of calculation which he described. In view of the fact, however, that certain details of his method are open to criticism, it has seemed appropriate to the present writers to consider the principles underlying the subject, and to determine if possible the most logical basis and method for comparison. From Schaller's paper, the mineralogist or chemist may perhaps be led to infer (1) that the ordinary methods of calculation furnish only a rough measure of the degree of approximation of a chemical analysis of a mineral or chemical compound to the values derived from its chemical formula; and (2) that by a somewhat involved calculation the analysis can be expressed in more accurate form.

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] Jour. Wash. Acad. Sci., **3**: 97–98. 1913.

[3] The term *mol number* is here suggested as an appropriate name for the number obtained by dividing the weight percentage of a chemical substance in any given chemical analysis by its proper molecular (respectively atomic) weight. Such numbers have usually been called *molecular ratios*, but they are, rather, numbers indicating the number of mols (gram-molecules) of each substance present in n grams of the material analyzed where n is the sum of the analysis. The terms *molecular ratios* or *molecular proportions* apply logically only to the numbers of the chemical formula. Thus in the analysis cited below, the chemical formula numbers or molecular ratios are

$S : As : (Ag + Cu) = 11 : 2 : 8$, while the mol numbers from the analysis are $S = 0.5444$; $As = 0.1008$; $(Ag + Cu) = 0.3975$. To use the term molecular ratios indiscriminately for both sets of numbers is not conducive to precise statement and is not to be recommended. The term *mol number* seems preferable to *molecular number* or molecular quotient (Molekularzahl Molekularquotient) which are in current use in German. The writers are indebted to Drs. Washington and Niggli for detailed discussion of the proposed term.

The underlying purpose of such calculations is not, however, to improve a chemical analysis by mathematical manipulation, which is obviously impossible, but to obtain a logical basis of comparison for the given analysis with the analysis calculated from the chemical formula. In the following paragraphs the different methods which are available for such comparisons will be discussed with reference to their accuracy and general applicability. It will be shown that the best general method is to compare the actual analysis of the mineral with the weight percentage analysis derived from its chemical formula. This method is, moreover, in common use. The method suggested by Schaller is not only inferior to this and to the other methods considered below, but it is incorrect in principle in certain details.

The problem is based on Dalton's fundamental law of simple atomic or molecular ratios, namely, that in a homogeneous chemical substance in which the relations are not veiled by solid solution, the atomic and molecular proportions can be expressed by small whole numbers. In practice, however, we find that because of various sources of error (lack of purity of material analyzed, inaccuracy in chemical methods and impurities in reagents employed, errors in atomic weights, personal equation of analyst), the actual data of a mineral analysis, after reduction to mol numbers, only approximate whole numbers in their ratios, the deviations being usually small and to be treated as errors of observation. In the present problem, only the final results of an analysis are given and the above sources of error can not therefore be differentiated and properly weighted, but have to be considered together and all analytical data equally weighted. It should be noted that in chemical data of this character, the systematic errors are relatively large, and that, furthermore, they can not be distinguished in the analytical data, as given, from the accidental errors. Too refined mathematical treatment is, therefore, unnecessary and misleading. For the sake of completeness, however, the various available methods will be considered below, even tho several of them are hardly to be recommended for the reasons cited above.

From the mol numbers of an analysis we infer by inspection the

molecular ratios or simple chemical formula numbers, and then proceed to determine how close the agreement is between the observed values and those deduced from the inferred chemical formula. This can be done by several different methods, which, however, are not all equally rigorous. The best and most logical methods are based on a comparison between the given analysis (weight percentages) and the weight percentage analysis computed from the inferred chemical formula. Comparisons can also be made between the mol numbers and the inferred molecular ratios, but these are not strictly correct in principle. They have, however, often been adopted, by chemists and mineralogists, and merit, therefore, a brief word of description after the more rigorous methods have been presented in detail. In all the methods the assumption is made that after proper reduction of the weight percentages of the given mineral analysis, the chemical formula numbers (molecular ratios) can be inferred by simple inspection; this signifies that in the case of solid solution we know, or are able to determine, the particular molecules which should be considered together.

First method. In this method the chemical formula numbers are first multiplied by the proper molecular (respectively atomic) weights and the corresponding weight numbers (x) obtained. These in turn are multiplied by a factor m which is determined by the least square method and furnishes the most accurate values (y') for the weight percentages. To find m we assume in accord with usual practice that the theoretical weight numbers (x) derived from the molecular ratios are free from error and that the observed quantities (y, the weight percentages of the analysis) contain errors of observation. Since the two series of numbers stand in a constant ratio m to each other we have the observation equations

$$y_1 = mx_1,\ y_2 = mx_2,\ \ldots\ y_n = mx_n. \qquad (1)$$

The general equation, $y = mx$, is the equation of a straight line passing thru the origin. The rigorous solution consists, therefore, in adjusting the straight line thru the n given points. A higher degree of precision would be obtained by considering the

origin as an observed point but this assumption seems in the present instance unnecessary and incorrect in principle.

To obtain the required solution let the equations be put in the form

$p_1y_1 - mp_1x_1 = p_1v_1,\ p_2y_2 - mp_2x_2 = p_2v_2,\ \ldots\ p_ny_n - mp_nx_n = p_nv_n$ (2)

in which $v_1, v_2 \ldots v_n$ are the respective residuals or the differences between the observed values $(y_1, y_2, \ldots y_n)$ and the computed values $(y'_1, y'_2, \ldots y'_n)$; $p_1, p_2, \ldots p_n$ are arbitrary weights assigned to the corresponding observation equations. By making now the sum of the weighted squares of the residuals $(p_1v_1^2 + p_2v_2^2 + \ldots + p_nv_n^2)$ a minimum we obtain the best possible solution of the equation for m, namely,

$$m = \frac{p_1x_1y_1 + p_2x_2y_2 + \ldots + p_nx_ny_n}{p_1x_1^2 + p_2x_2^2 + \ldots + p_nx_n^2},$$

an expression which reduces to

$$m = \frac{x_1y_1 + x_2y_2 + \ldots + x_ny_n}{x_1^2 + x_2^2 + \ldots + x_n^2} \qquad (3)$$

when we assume that the weights $(p_1, p_2, \ldots p_n)$ to be assigned to the observation equations are all unity.

To apply this method to the analysis cited by Schaller we ascertain first the mol numbers (Column 2) by dividing the weight

	1	2	3	4	5	5a	6	6a	7	7a	8	8a
	WEIGHT PERCENTAGES (y) OBS.	MOL NUMBERS	MOLECULAR RATIOS	WEIGHT NUMBERS (x)	WEIGHT PERCENTAGES (y') COMP.	RESIDUALS o-c		o-c		o-c		o-c
S..	17.46	0.5444	11	352.79	17.53	−.07	17.54	−.08	10.981	+.019	10.964	+.036
As	7.56	0.1008	2	150.00	7.45	+.11	7.45	+.11	2.033	−.033	2.030	−.030
Ag	59.22	0.2744*	8	1191.85	59.21	+.01	59.24	−.02	8.018	−.018	8.006	−.006
Cu	15.65	0.1231*		314.97	15.65	.00	15.66	−.01				
	99.89	1.0427	21	2009.61	99.84		99.89	.00	21.032		21.000	.000

* Considered as (Ag_2) and (Cu_2) respectively. Sum = 0.3975

percentages of column 1 by the proper atomic (respectively molecular) weights;[4] from these mol numbers, we have

$$S : As : (Ag_2 + Cu_2) = 0.5444 : 0.1008 : 0.3975$$

and infer that the correct chemical formula numbers are

$$S : As : (Ag_2 + Cu_2) = 55 : 10 : 40 = 11 : 2 : 8.$$

These numbers (column 3) are then multiplied by the proper atomic (respectively molecular) weights and the (x) values of the equations (1) obtained (column 4). The value of m is now found from equation (3) by dividing the sum of the products of the observed values (y) (column 1) and the theoretically correct values (x) (column 4) by the sum of the squares of (x). On multiplying the (x) values by the value of m ($= 0.049682$) thus computed we find the values in column (5); the differences between the observed (y) and computed (y') values ($o - c$, column 1 − column 5) are a proper measure of the degree of approximation of the actual analysis to that computed from the inferred chemical formula. The rigorous test would consist in computing the probable error of a single observation but this procedure is perhaps unnecessary for data of the character here considered.

Second method. This method is a mathematical refinement of the first method but it does not give values which are of sufficiently greater precision to warrant the extra labor involved in computation nor does the assumption that (x) contains errors of observation seem to be rigorously justified unless errors in the atomic weights are of sufficient magnitude to be taken into account. In this method it is assumed that both the (x) and the (y) values of equations (1) contain errors of observation. The proper value of m to meet the conditions is then obtained from the equation

$$m^2 - \left(m_2 - \frac{1}{m_1}\right) m - 1 = 0 \qquad (4)$$

wherein

[4] In his paper Schaller did not state the atomic (respectively molecular) weights which he used in his computations. They are readily found, however, by dividing the numbers of the first column by the corresponding ones of the second. They are S = 32.07; As = 75.00; (Ag_2) = 215.82; (Cu_2) = 127.13.

$$m_1 = \frac{x_1y_1 + x_2y_2 + \ . \ . \ . \ + x_ny_n}{x_1^2 + x_2^2 + \ . \ . \ . \ + x_n^2}$$

$$m_2 = \frac{y_1^2 + y_2^2 + \ . \ . \ . \ + y_n^2}{x_1y_1 + x_2y_2 + \ . \ . \ . \ + x_ny_n}.$$

In these equations the weights of (x) and (y) and of all observation equations are assumed to be unity; m_1 is the value of m in equations (1) when (x) is assumed to be correct and (y) to contain the errors of observation; m_2 is the value of m in equations (1) when (y) is assumed to be correct and (x) to contain slight errors. On applying this method to the above analysis we find that the values obtained are identical with those in column 5 to the second decimal place.

Third method. The results obtained by this method are only approximately correct but they are of sufficient accuracy to be satisfactory for most analyses and are, moreover, readily computed, the computation consisting simply in reducing the weight numbers (x) (Column 4) proportionately, so that their sum (column 6) is equal to that of the given analysis (column 1), the assumption being that when the two analyses have the same sum (either the actual sum of the given analysis or 100.00), we have a common basis for comparison. The differences (column 6a) between the observed weight percentages (column 1) and those computed by this method (column 6) are then an approximate, but satisfactory measure of the agreement of observation with theory. This method is, for general purposes, the simplest and best. Mathematically it can be stated from a somewhat different viewpoint, altho the computations are the same. If we assume that the sum of the weighted residuals $(p_1v_1 + p_2v_2 + \ . \ . \ . \ + p_nv_n)$ in equations (2) is zero, the resulting equation gives

$$m' = \frac{p_1y_1 + p_2y_2 + \ . \ . \ . \ + p_ny_n}{p_1x_1 + p_2x_2 + \ . \ . \ . \ + p_nx_n}, \tag{5}$$

an equation which reduces to

$$m' = \frac{y_1 + y_2 + \ . \ . \ . \ + y_n}{x_1 + x_2 + \ . \ . \ . \ + x_n} \tag{6}$$

when we assign equal weight to all the observation equations. In Schaller's analysis, the factor

$$m' = \frac{99.89}{2009.61} = 0.049706$$

which is only slightly different from the factor m obtained by the least square method. To find the required value for S in the above analysis by this method, we multiply the weight number 352.79 (column 4) by the factor $m' = 0.049706$ and obtain the value 17.54 listed in column 6; the remaining values of column 6 are obtained from column 4 by multiplying by the same factor.

To impose the conditions (1) that the sum of the residuals shall vanish and (2) that the sum of their squares shall be a minimum, we write the observation equations in the general form

$$y = a + mx,$$

and adjust them by the usual least square method. There seems, however, to be no justification for adopting such a procedure here.

Fourth, fifth and sixth methods. These methods are identical with the three preceeding methods except that the adjustments are made between the mol numbers and the molecular ratios. Thus the mol numbers may be taken as the observed values (y) and the molecular ratios as the theoretically correct values (x) to be used in the observation equations (1). Adjustment can then be made by any one of the methods described above. Thus in method (4), the factor m of observation equations (1) is found from equation (3) by considering the mol numbers (column 2) the (y) values and the molecular ratios (column 3) the (x) values. The final values are then obtained by multiplying the (x) values (column 3) by the factor m thus computed. In method (5) the same values of (x) and (y) are used and the proper value for m computed from equation (4) above. Similarly in method (6) the proper value for m' is computed from equation (6). The results obtained by these three methods are, however, theoretically inferior to those of the first three methods, for the reason that the mol numbers are obtained from the weight percentages by dividing them by the proper molecular (respectively atomic)

weights, and are therefore differently weighted because the molecular (respectively atomic) weights are different. In the present case these objections do not seriously affect the results obtained, but the objection is nevertheless valid and the methods are in error to that extent.

Seventh, eighth and ninth methods. In these methods the adjustments are made on the assumption that the mol numbers are theoretically correct (x values), while the molecular ratios (y) contain the errors of observation. This is a still further departture from correct theory, and neither these methods nor those noted in the last paragraph are to be recommended. The values obtained by the seventh method involving adjustment by least squares are listed in column 7, while the differences ($o - c$) between columns 3 and 7 are given in column 7a. Similarly, the results obtained by use of the ninth method, which corresponds to method 3, are given in column 8 and the differences ($o - c$) in column 8a. It may be noted here that insofar as the numerical computations are concerned, it is immaterial which set of quantities (x or y) are assumed to contain errors of observation when equation (6) is used, but different results are obtained when the quantities are adjusted by means of equations (3) and (4).

Schaller's method is in error in the following details of principle:

1. Comparisons are made between mol numbers and molecular ratios on the assumption that the mol numbers are theoretically correct while the molecular ratios contain the errors of observation. The objections cited under methods 7 to 9 apply, therefore, to his method.

2. The numbers given in his column (2), page 98, are of unequal weight and the arithmetic mean is not, therefore, a correct average.

3. The final values in his last column near the bottom of page 98 are obtained by dividing the computed numbers in his column (3), page 98, by the molecular ratios. These values are accordingly of different degrees of approximation because differently weighted.

4. His method may be stated in the form of an equation by putting

$$p_1 = \frac{1}{x_1},\ p_2 = \frac{1}{x_2} \quad . \quad . \quad . \quad p_n = \frac{1}{x_n}$$

in equation (5). Since the weights are here inversely proportional to the (x) values, it follows that small molecular ratios are adjusted more accurately than the larger numbers.

Summary. Of the methods available for comparing the observed results of a mineral analysis with those obtained from the chemical formula to which the analysis corresponds approximately, the best method is to ascertain first the weight numbers (derived from the chemical formula by multiplying these ratios by the proper molecular weights), and then to adjust these values to the given analysis by the least square method. Since the computations involved are, however, somewhat laborious, and furthermore, since there are a limited number of observations and the systematic errors of observation are, in general, large as compared with the accidental errors, the simple method (3) (equation 6) is preferable for general use. It furnishes results which are very nearly correct and consists simply in reducing the weight numbers proportionately so that their sum is equal to that of the given analysis. In other words, we compare the actual analysis directly with the weight percentage analysis computed from the inferred chemical formula, both analyses having a common sum. The differences between the observed and computed values are then a sufficient measure of the degree of agreement of observation with theory. The two general formulas (3) and (6) furnish the best solutions of the present problem. In these formulas y may be taken to represent weight percentages, mol numbers or molecular ratios, while x represents respectively the weight numbers, the molecular ratios or the mol numbers. Equation (3) always gives a more precise adjustment, but equation (6) is in general sufficiently accurate for the computations here considered. The relation between weight percentages and weight numbers is rigorous. The relations between mol numbers and molecular ratios are lacking in rigor, but are usually sufficiently accurate for the purpose.

PHYSICS.—*A new thermal microscope for the measurement of the optical constants of minerals at high temperatures.* FRED. EUGENE WRIGHT, Geophysical Laboratory.

With this microscope (fig. 1) three optical constants—birefringence, extinction angle, optic axial angle—of a properly ori-

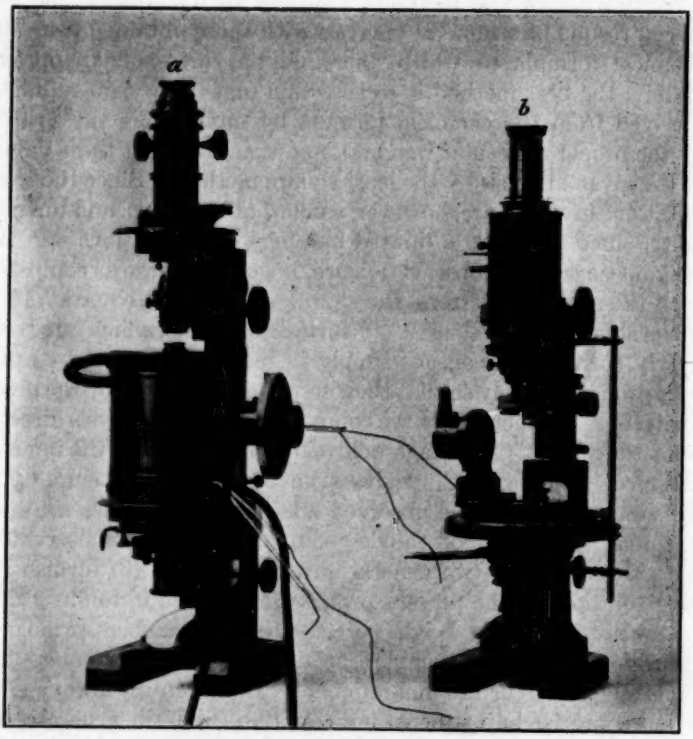

Fig. 1

ented crystal plate can be measured accurately at any temperature between 10°C and 1200°C. Above 1200° the intensity of illumination from the furnace itself is so great that it tends to veil the optical phenomena produced by the polarized light waves transmitted thru the plate. The thermal microscope consists

of two distinct parts: (1) a petrographic microscope equipped with a suitable device for simultaneous rotation of the nicols, either by means of gear wheels connected by a bar (fig. la) or by means of a direct connecting bar (fig. 1b), the second method being the more accurate and satisfactory; (2) an electric resistance furnace *A* (fig. 2) which is enclosed within the water jacket *W* (fig. 2). The details of construction of this furnace are shown in vertical section in figure 2. The furnace consists of two alundum

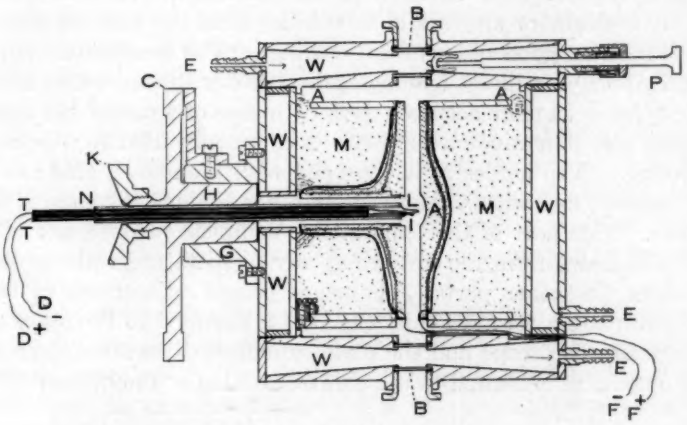

Fig. 2

tubes made especially for the purpose and wound on the outside, in helical grooves of 1 mm. pitch, with platinum wire 0.35 mm. in diameter. It is then coated with alundum cement and finally baked at 1200° to 1400° for several hours. In this furnace the relatively small openings at the ends and the side, the enlargement at the center and the close winding of the heating coil are arranged to insure uniformity of heating in the central space where the crystal plate is heated and its temperature measured.

The water jacket consists of a hollow brass cylinder and separate hollow end plates each of which is provided with an intake and outlet *E* for the circulating water. Into each end plate a plunger *P* is fitted for wiping away the air bubbles which happen

to collect between the two glass windows *B* and thus to disturb the field of view. To the cylinder part of the jacket a support *G* is attached with conical center bearing for the crystal holder. The crystal plate whose optical constants are to be determined is held in position by platinum jaws (*L* fig. 2) which fit into and project beyond the porcelain tube *N*, which in turn is held in position by the rotating holder *H*. The thermoelement wires *D* are passed thru the larger tube *N* in small porcelain tubes *T* and extend beyond these so that the thermoelement junction is directly beneath or above and in contact with the mineral plate, thus insuring good temperature readings. The temperatures are read either on a direct reading millivoltmeter (Siemens and Halske type) or in more accurate work by means of a mirror galvanometer and potentiometer system as commonly used in this laboratory.[1] The holder *H* is equipped with a circle *C*, graduated to degrees, and with a clamp screw *K* for keeping the tube *N* in place. This part of the apparatus is complete in itself and can be withdrawn from the furnace at any temperature without disturbing the other parts. To insure proper adjustment of the crystal plate a second holder (fig. 1b) is clamped to the stage of a second microscope and the plate so mounted that the plane of its optic axes is normal to the axis of rotation of the holder.

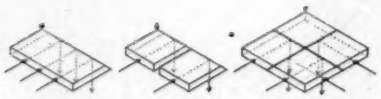

Fig. 3

For this adjustment a device for autocollimation has been used which has proved serviceable and promises to be of value in other autocollimating instruments. A thin cover slip of the shape indicated in figure 3a with one edge vertical and the opposite edge inclined 45° to the vertical, is placed in the rear focal plane of the low power objective. Light from a Nernst filament, sent thru the plate to the inclined edge, is totally reflected

[1] Carnegie Institution of Washington, Pub. **31**, 1905; **157**, 68, 1911.

and passes thence through the objective to the mineral plate, where it is again reflected and appears, after its return through the objective, as a sharp bright line in the dark field. When the mineral plate is normal to the axis of the lens system, the bright line is practically covered, thus enabling the observer to make very accurate adjustments.[2]

This method has been improved by using two cover glasses as indicated by figure 3b, the space between the glasses serving to mark the center. The complete cross has also been obtained by means of cover glasses ground as illustrated in figure 3c. The grinding and mounting of four such cover glasses is, however, difficult and requires considerable skill to be accomplished satisfactorily.[3]

After the crystal plate has been mounted and adjusted and the thermoelement wires correctly placed, the holder *H* is inserted into its support *G* on the water jacket (fig. 2) and the mineral plate thus introduced into the furnace in a position ready for the measurement both of its optical constants and of its temperature.

The *birefringence* of a mineral plate is measured on this microscope by the method used on the thermal microscope described several years ago.[4] The thickness of the plate is determined before insertion into the furnace. The change in thickness due to expansion on heating is so slight that it is negligible for most measurements of birefringence. The path-difference of the emergent waves from the crystal plate in the furnace is measured by means of a graduated compensating wedge.[5]

Extinction angles are measured by means of a biquartz wedge

[2] This scheme for autocollimation is somewhat similar to that suggested by Nutting in this Journal **2**, 404, 1912. In his arrangement a reflecting cover glass is used on end with the result that only a small part of it is in focus at any setting of the eyepiece while in the scheme outlined above the entire cover glass is in sharp focus and the field is less disturbed.

[3] These different types of cover glasses were satisfactorily ground for the writer by the Bausch and Lomb Optical Company.

[4] Am. J. Sci. (4) **27**, 43. 1909.

[5] Am. J. Sci. (4) **29**, 417. 1910; Carnegie Institution of Washington, Pub. **158**, 102. 1911.

plate[6] combined with rotating nicols. This plate is useful for determining positions of total extinction of a mineral even at high temperatures where the strong illumination of the furnace field tends to cover up the interference colors from the mineral plate.

The *optic axial angle* is measured directly on the graduated circle *C* (fig. 2), the crystal plate being rotated until each of its two optic axes coincides with the axis of the microscope (tested by rotation of the nicols, as in the universal stage methods); the angular distance between the two positions of coincidence is read directly on the graduated circle. These positions are sharply marked and the error of the measurement of the optic axial angle on a favorable section is not over $\pm 1°$ even at relatively high temperatures.

This thermal microscope has proved so satisfactory in practice that an extended series of measurements on selected natural minerals of known composition has been commenced with a view to determine not only the changes in their optical constants but also their inversion and melting temperatures, these last temperatures to be checked by means of the accurate temperature measuring methods now in use in the Geophysical Laboratory. At the same time the refractive indices and in some instances changes in crystal angles will be ascertained by the use of another furnace attached to the two circle goniometer and to be described in a later communication.

[6] Am. J. Sci. (4) **26**, 377, 1908; Carnegie Institution of Washington, Pub. **158**, 139. 1911.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE GEOLOGICAL SOCIETY OF WASHINGTON

The 265th meeting was held in the lecture room of the Cosmos Club, February 12, 1913.

An informal communication was presented:

Cone in cone structure in coal from St. Anthony, Idaho: E. G. WOODRUFF. Cone in cone structure is not uncommon in clay and shale, but unusual in coal. The specimens exhibited from the St. Anthony coalfield, Idaho, show this structure well developed on the surface but not developed within the specimens, tho shearing is shown. Bed from which the sample is taken is crushed and faulted. Slickensiding is common. The cone in cone genetically in this case seems to be closely related to slickensiding. The complete explanation is not offered.

The formal communications were:

Certain metallic minerals as precipitants of silver and gold. CHASE PALMER and EDSON S. BASTIN. The paper will be published in no. 2, vol. 8, of Economic Geology, and in shorter form in the Transactions (New York meeting) of the American Institute of Mining Engineers.

Time relations of glacial lakes in the Great Lakes region: FRANK LEVERETT. The following tabulated statement of the order of development of lakes in the several basins sets forth the tentative correlation based upon a study of the moraines, lake outlets, and other features which bear upon correlations. The writer is responsible for the present tabulation but is indebted to various other geologists for data bearing upon the direction of outlet of the several lakes at different lake stages.

Order of development of glacial lakes

1. General recession of ice border but with some oscillation.
   Lake Maumee, discharge (a) By Fort Wayne to Wabash River.
   (b) By Imlay outlet to Lake Chicago.
   Lake Saginaw, discharge in later stage by Grand River outlet to Lake Chicago.
   Lake Chicago, discharge by Chicago outlet to Illinois River.
2. General recession of ice border.
   Lake Arkona, discharge by Grand River outlet to Lake Chicago.
   Lake Chicago, discharge by Chicago outlet to Illinois River.

3. Readvance of ice border.
   Lake Whittlesey, discharge by Ubly outlet to Lake Saginaw.
   Lake Saginaw, discharge by Grand River outlet to Lake Chicago.
   Lake Chicago, discharge by Chicago outlet to Illinois River.
4. General recession of ice border.
   Lake Wayne, discharge by Syracuse outlet to Mohawk River.
   Lake Chicago, discharge by Chicago outlet to Illinois River.
   Lake Duluth, discharge by St. Croix outlet to Mississippi River.
5. Readvance of ice border.
   Lake Warren, discharge by Grand River outlet to Lake Chicago.
   Lake Chicago, discharge by Chicago outlet to Illinois River.
   Lake Duluth, discharge by St. Croix outlet to Mississippi River.
6. General recession of ice border.
   Lake Lundy, Elkton, Dana discharge by Syracuse outlet to Mohawk Valley.
   Lake Chicago, discharge by Chicago outlet to Illinois River.
   Lake Duluth, discharge by St. Croix outlet to Mississippi River.
7. General recession of ice border.
   Lake Iroquois, discharge by Mohawk outlet.
   Lake Erie, discharge by Niagara outlet to Lake Iroquois.
   Lake Algonquin, discharge by (a) Trent outlet to Lake Iroquois.
   (b) By St. Clair outlet to Lake Erie.
   Lake Agassiz, discharge by River Warren to Mississippi River.
8. Ice border north of Great Lakes watershed.
   Lake Nipissing, discharge by (a) Ottawa outlet to Champlain Sea.
   (b) Part discharge by St.Clair outlet to Lake Erie.
   (c) Full discharge by St. Clair outlet
   Lake Erie, discharge by Niagara outlet to Lake Ontario or Champlain Sea.
   Champlain Sea in St. Lawrence valley.
   Close of Lake Agassiz, probably eastward discharge to Lake Algonquin followed by northeastward drainage to Hudson Bay.
9. Modern lakes discharging by St. Lawrence River.

R. W. RICHARDS, *Secretary.*

The 266th meeting was held in the lecture room of the Cosmos Club, February 26, 1913, and the following informal communication was presented:

Asphalt in a basaltic amygdaloid from British Columbia: NORMAN L. BOWEN.

The formal communications were:

The zinc-lead deposits of the Yellow Pine district, Nevada: J. M. HILL. The Yellow Pine district is in the southwestern part of Clark County, Nevada, near the California line. The mines are located on both sides of the southern Spring Mountains over an area of nearly 400 square

miles. Jean, on the San Pedro, Los Angeles, and Salt Lake railroad is the principal shipping point. Goodsprings, 8 miles northwest of Jean with a population of 200 is the largest town.

The ore deposits are of zinc and lead and form very irregular replacements which usually occur in more or less crystalline upper Mississippian limestone. They are found thru a vertical range of 3000 feet and do not seem to be restricted to any particular member of the sedimentaries. The principal factors in the localization of the ore bodies appear to be the presence of joints and crushed zones which in general strike east and west or nearly north and south, and are in most places nearly vertical.

The zinc and lead ores are usually closely associated. The ratio of zinc to lead, however, is extremely variable even in the same ore body. In general, the lead content is higher in the upper part of the ore bodies.

The only sulphide mineral common to these ores is galena. Part is probably original but some is undoubtedly secondary. At one place in the Potosi mine a small body of sphalerite ore was found entirely surrounded by oxidized zinc ores. This ore is considered to represent the primary ore, but it may be enriched. The sphalerite is intergrown with calcite and a little galena, and is iron-bearing.

The ores now being mined in the district consist of white or red iron-stained smithsonite, with some cerussite, anglesite, and galena. Calamine is not abundant and where seen is usually developed in the latest open water-courses in the other ore. Hydrozincite is sometimes present in fairly large masses in the ore bodies near the surface and often shows as a white coating on the croppings.

It is thought that the present bodies of carbonate ores have resulted in part from alteration of sulphide ores in place and in part from a downward concentration of the metals by surface waters which followed the fractures in their movement towards ground-water level.

Pre-Wisconsin drift in the region of the Glacier National Park, Montana: W. C. Alden and Eugene Stebinger. An abstract of this paper was published in the preliminary list of papers for the New Haven meeting of the Geological Society of America. The full paper is to be published in vol. 24 of the Bulletin of the Society.

Frank L. Hess, *Secretary.*

THE SEMI-CENTENARY ANNIVERSARY OF THE NATIONAL ACADEMY OF SCIENCES

The National Academy of Sciences will celebrate the 50th anniversary of its foundation at the National Museum in Washington April 22–24 inclusive. The program will include the following addresses, to which the members of the Washington Academy of Sciences and of its affiliated societies are cordially invited.

Tuesday, April 22.—Opening session, 11 a.m. Welcome by President IRA REMSEN.

The relation of science to higher education in America: President ARTHUR T. HADLEY, of Yale.

International coöperation in research: Prof. ARTHUR SCHUSTER, Secretary of the Royal Society.

Afternoon session, 3 p.m.—*The earth and sun as magnets:* Dr. GEORGE E. HALE, Director of the Mount Wilson Solar Observatory.

Wednesday, April 23, 10.30 a.m.—*On the material basis of heredity:* Prof. THEODOR BOVERI of the University of Würzburg.

The structure of the universe: Prof. J. C. KAPTEYN of the University of Groningen.

All addresses will be in English.

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